Environmental Issues and World Energy Use

In the coming decades, global environmental issues could significantly affect patterns of energy use around the world. Any future efforts to limit carbon emissions are likely to alter the composition of total energy-related carbon emissions by energy source.

Global climate change is a wide-reaching environmental issue that has received increased attention in recent years. Carbon dioxide, one of the most prevalent greenhouse gases in the atmosphere, has two major anthropogenic (human-caused) sources: the combustion of fossil fuels and changes in land use. Net releases of carbon dioxide from these two sources are believed to be contributing to the rapid rise in atmospheric concentrations since pre-industrial times. Because estimates indicate that approximately 80 percent all anthropogenic carbon dioxide emissions currently come from fossil fuel combustion, world energy use has emerged at the center of the climate change debate [***1***].

Global Outlook for Carbon Dioxide Emissions

The *International Energy Outlook 2002* (*IEO2002*) projects emissions of energy-related carbon dioxide, which, as noted above, account for the majority of global anthropogenic carbon dioxide emissions. Based on expectations of regional economic growth and dependence on fossil energy in the *IEO2002* reference case, global carbon dioxide emissions are expected to grow more rapidly over the projection period than they did during the 1990s. An increase in fossil fuel consumption, particularly in developing countries, is largely responsible for the expectation of fast-paced growth in carbon dioxide emissions. Factors such as population growth, rising personal incomes, rising standards of living, and further industrialization are expected to have a much greater influence on levels of energy consumption in developing countries than in industrialized nations. Energy-related emissions are projected to grow most rapidly in China, the country expected to have the highest rate of growth in per capita income and fossil fuel use over the forecast period.

Carbon intensity—the amount of carbon dioxide emitted per dollar of gross domestic product (GDP)—is projected to improve (decrease) throughout the world over the next two decades (Table 25). The steepest rates of improvement are, for the most part, expected to occur among the transitional economies of Eastern Europe and the former Soviet Union (EE/FSU). In the FSU, economic recovery from the upheaval of the 1990s is expected to continue throughout the forecast. The FSU nations are also expected to replace old and inefficient capital stock and increasingly use less carbon-intensive natural gas for electricity generation and other end uses

Table 25. Carbon Intensities for Selected Countries and Regions, 1999-2020
(Metric Tons Carbon Equivalent per Thousand 1997 Dollars of GDP)

Country or Region	1999	2005	2010	2020	Annual Percent Change, 1999-2020
United States	168	159	146	124	-1.4
Canada	214	194	178	155	-1.5
Mexico	230	234	218	185	-1.0
United Kingdom	109	104	96	81	-1.4
France	72	68	62	56	-1.2
Germany	105	98	90	78	-1.4
Australasia	223	203	187	159	-1.6
Former Soviet Union	1,068	900	785	589	-2.8
Eastern Europe	558	482	411	305	-2.8
China	645	555	493	392	-2.3
India	511	457	403	315	-2.3
South Korea	218	201	177	142	-2.0
Brazil	108	100	100	94	-0.6
Turkey	268	253	229	191	-1.6

Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2005-2020:** EIA, World Energy Projection System (2002).

in place of more carbon-intensive oil and coal. Eastern European nations have been in economic recovery longer than has the FSU, and natural gas is expected to continue to displace coal use in the region, resulting in an average 2.8-percent annual improvement (decrease) in carbon intensity for Eastern Europe as a whole.

The developing Asian countries of China and India are also expected to enjoy a fairly rapid improvement in carbon intensity over the projection period, primarily as a result of rapid economic growth rather than a switch to less carbon-intensive fuels. Both China and India are projected to remain heavily dependent on fossil fuels, particularly coal, in the *IEO2002* reference case, but their annual GDP growth is projected to average 6.6 percent, compared with an expected 4.4-percent annual rate of increase in fossil fuel use from 1999 to 2020.

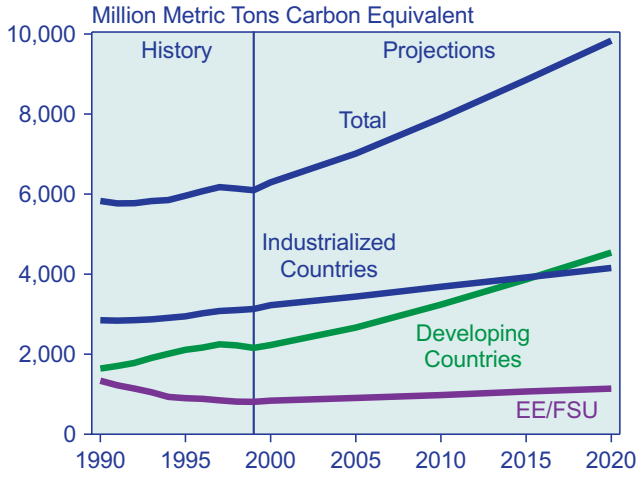
In 1999, carbon dioxide emissions from industrialized countries accounted for 51 percent of the global total, followed by developing countries at 35 percent and the EE / FSU at 13 percent. By 2020, developing countries are projected to account for the largest share of world carbon dioxide emissions, at 46 percent, followed by the industrialized world at 42 percent and the EE / FSU at 12 percent. The *IEO2002* projections indicate that carbon dioxide emissions from developing countries could surpass those from industrialized countries around 2015 (Figure 88).

In the industrialized world, almost one-half of all energy-related carbon dioxide emissions in 1999 came from oil use, followed by coal at 30 percent (Figure 89). Over the forecast period, oil is projected to remain the primary source of carbon dioxide emissions in industrialized countries because of its continued importance in the transportation sector, where there are currently few economical alternatives. Natural gas use and associated emissions are projected to increase substantially, particularly for electricity generation. By 2020, the share of natural-gas-related emissions is expected to be approximately equal to that of coal at 26 percent.

The United States is currently the largest energy consumer in the industrialized world, accounting for the majority of its energy-related carbon dioxide emissions. Natural gas and coal use for electricity generation in the United States are projected to increase over the forecast period, whereas generation from nuclear energy is expected to decline after 2010. No new nuclear plants are expected to be constructed in the United States by 2020, given the more favorable economics of competing technologies. As a result, U.S. electricity generation is projected to become more carbon intensive over the forecast period.

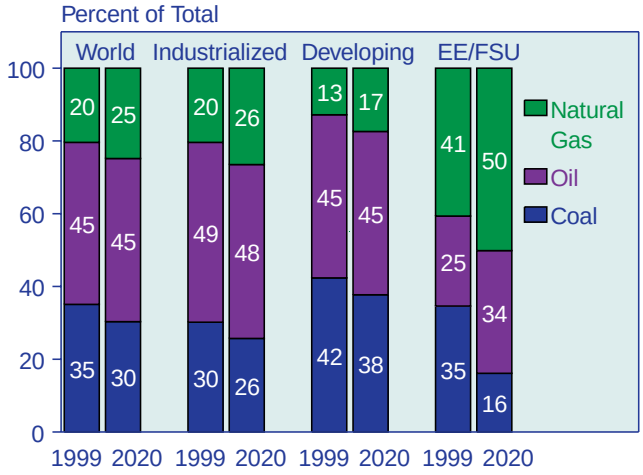
With the exception of Australia, most other industrialized countries rely much less heavily on coal to meet domestic energy needs than does the United States. In Western Europe, coal consumption is projected to continue to decline over the forecast period as natural gas consumption, particularly for electricity generation, increases. The projected decline in Western Europe's carbon intensity, brought on by the continued shift in the overall energy supply toward more natural gas, is lessened somewhat by the projected decline in nuclear power generation after 2010. Germany and Sweden have committed to shutting down their nuclear power

Figure 88. World Carbon Dioxide Emissions by Region, 1990-2020



Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **Projections:** EIA, World Energy Projection System (2002).

Figure 89. Shares of World Carbon Dioxide Emissions by Region and Fuel Type, 1999 and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2020:** EIA, World Energy Projection System (2002).

industries, and other European countries are considering similar proposals. Electricity generation from other non-emitting energy sources, such as hydroelectricity and wind power, is not expected to fully offset the drop in nuclear energy production in these regions.

In the transitional economies of the EE/FSU region, the majority of energy-related carbon dioxide emissions currently come from natural gas combustion. Coal production and consumption in the EE/FSU declined as a result of economic reforms and industry restructuring during the 1990s, bringing about an increase in the natural gas share of the energy and emissions mix during the period. With further development of the vast natural gas reserves in Russia and the Caspian Sea region, natural gas is expected to continue to displace coal. Oil consumption is also projected to increase in the FSU, particularly for transportation and power generation, as Soviet-era nuclear reactors are retired in the coming years. As a result, both natural gas and oil are projected to account for increasing shares of the region's total carbon dioxide emissions, reaching 47 percent and 34 percent, respectively, by 2020.

With further restructuring of the coal mining industries in Poland and the Czech Republic, declines in coal production and consumption are expected to continue. On the other hand, natural gas consumption in Eastern Europe is expected to increase significantly, driven in part by the need for many countries to meet the strict environmental standards required for membership in the European Union (EU). As a result of the projected changes in the energy mix, Eastern Europe's carbon intensity is expected to decline more than in any other world region over the forecast period. However, the decline in Eastern Europe's carbon intensity is not expected to keep pace with the expected growth in its total energy consumption. Consequently, annual carbon dioxide emissions in the region are expected to increase by nearly 26 percent between 1999 and 2020.

Compared with most of the industrialized countries, a much larger share of energy consumption in developing countries (particularly in Africa and Asia) comes from biomass, which includes wood, charcoal, animal waste, and agricultural residues. Because data on biomass use in developing nations are often sparse or inadequate, *IEO2002* does not include the combustion of biomass fuels in its coverage of current or projected energy consumption and associated carbon dioxide emissions, except for the United States.

Of the fossil fuels, oil and coal currently account for the majority of total energy-related carbon dioxide emissions in the developing world, and they are projected to remain the dominant sources of emissions throughout the forecast period. China and India are expected to continue to rely heavily on domestic coal supplies for electricity generation and industrial activities. Most other developing regions are expected to continue to depend on oil to meet the majority of their energy needs, especially in light of the projected increase in transportation energy demand.

The largest increases in energy consumption and carbon emissions are projected for China, given the expectations for continued economic expansion and population growth. Coal reserves are abundant in China, and access to other energy fuels is limited in many parts of the country. Second only to developing Asia in terms of projected growth in energy consumption and carbon dioxide emissions, is Central and South America. Many countries in the region, most notably Brazil, have relied heavily on hydropower to provide the majority of their electricity. Natural gas is expected to take on an increasing share of the energy mix in Central and South America over the forecast period, however, as the countries continue their efforts to lessen dependence on hydropower by tapping into the region's large natural gas reserves. As a result of the expected change in the region's fuel mix, coupled with an increase in overall energy demand, carbon dioxide emissions from Central and South America are expected to more than double between 1999 and 2020.

Future levels of energy-related carbon dioxide emissions in all regions are likely to differ significantly from *IEO2002* projections if measures to mitigate emissions are enacted, such as those outlined under the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC). The Kyoto Protocol, which calls for limitations on greenhouse gas emissions (including carbon dioxide) for developed countries and some countries with economies in transition, could have profound effects on future fuel use worldwide. Because the Kyoto Protocol has not yet come into force, the *IEO2002* projections do not reflect the potential effects of the treaty or of any other proposed climate change policy measures.

Issues in Energy-Related Emissions Policy

International Climate Negotiations

The world community's effort to address global climate change has taken place largely under the auspices of the UNFCCC, which was adopted in May 1992 and entered into force in March 1994. The ultimate objective of the UNFCCC is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" [***2***]. The most ambitious proposal coming out of subsequent conferences has been the Kyoto Protocol, which was developed in December 1997 at the third Conference of the Parties (COP-3). The terms of the

Kyoto Protocol call for Annex I countries to reduce their overall greenhouse gas emissions by at least 5 percent below 1990 levels over the 2008 to 2012 time period. Quantified emissions targets are differentiated by country. [26]

In addition to any domestic emission reduction measures that Annex I parties may choose to implement in order to meet their emission targets, the Kyoto Protocol allows the use of four "flexibility mechanisms" (sometimes called "Kyoto mechanisms"):

- *International emissions trading* allows Annex I countries to transfer some of their allowable emissions to other Annex I countries, beginning in 2008, for the cost of an emission credit. For example, an Annex I country that reduces its 2010 greenhouse gas emissions level by 10 million metric tons carbon equivalent more than needed to meet its target level can sell the "surplus" emission reductions to other Annex I countries. This trade would lower the seller's allowable emissions level by 10 million metric tons of carbon equivalent and raise the buyers' allowances by the same amount in total.

- *Joint fulfillment* allows Annex I countries that are members of an established regional grouping to achieve their reduction targets jointly, provided that their aggregate emissions do not exceed the sum of their combined Kyoto commitments. For example, EU countries have adopted a burden-sharing agreement that reallocates the aggregate Kyoto emission reduction commitment for the EU among the member countries [***3***].

- *The clean development mechanism* (CDM) allows Annex I countries, either through the government or a legal entity, to invest in emission reduction or sink enhancement projects in non-Annex I countries, gain credit for those "foreign" emissions reductions, and then apply the credits toward their own national emissions reduction commitments. The CDM, in principle, redistributes emission reductions from developing country parties to Annex I parties.

- *Joint implementation* (JI) is similar to the clean development mechanism except that the investment in emission reduction projects must occur within the Annex I countries.

The Kyoto targets refer to overall greenhouse gas emission levels, which encompass emissions of carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Hence, a country may opt for relatively greater reductions of other greenhouse gases emissions and smaller reductions of carbon dioxide, or vice versa, in order to meet its entire Kyoto obligation. Currently, carbon dioxide emissions account for the majority of greenhouse gas emissions in most Annex I countries, followed by methane and nitrous oxide [***4***].

Changes in emission levels resulting from human-induced actions that release or remove carbon dioxide and other greenhouse gases from the atmosphere via terrestrial "sinks" (trees, plants, and soils) are also allowed as "reductions" under the Protocol. The extent to which each Annex I party makes use of sinks and the mechanisms for counting the offsets will influence the amount of domestic emission reductions needed to comply with the Protocol.

Details of the operation of the Kyoto Protocol have been the subject of several UNFCCC meetings since COP-3. Some of the more contentious topics in the negotiation process have been the regime for enforcement of emission reduction commitments, the treatment of sinks, and rules for meeting national emissions targets via the Kyoto mechanisms. These issues were scheduled to be resolved at the November 2000 COP-6 meeting in The Hague, the Netherlands, but the meeting ended without agreement, and delegates reconvened in Bonn, Germany, in July 2001 to continue the COP-6 proceedings.

The main agreements reached at Bonn stipulate that forests, cropland, and grazing land management can be used to increase the amount of carbon sequestered in biologic sinks during the first commitment period (2008-2012), subject to some upper bounds; afforestation and reforestation projects can be eligible for the CDM; and no quantitative limits can be placed on emissions credit trading as a means of meeting the Kyoto commitments. The Bonn agreement also calls for 2 percent of the certified emissions reductions issued for any CDM project to go toward a fund for climate change adaptation projects in developing countries. The procedures and institutions needed to make the Kyoto Protocol fully operational were finalized by delegates at COP-7, held in Marrakech, Morocco, from October 29 through November 9, 2001.

Although the United States was present at COP-6 and COP-7, it did not take an active role in the negotiations. In March 2001, the United States announced that it would not support the Kyoto Protocol. The Protocol enters into force 90 days after it has been ratified by at

[26]Turkey and Belarus, which are represented under Annex I of the UNFCCC, do not face quantified emission targets under the Kyoto Protocol. The Kyoto Protocol includes emission targets for 4 countries not listed under Annex I—namely, Croatia, Liechtenstein, Monaco, and Slovenia. Collectively, the 39 parties facing specific emissions targets under the Kyoto Protocol are commonly referred to as "Annex B parties," because their targets were specified in Annex B of the Protocol.

least 55 Parties to the UNFCCC, including a representation of Annex I countries accounting for at least 55 percent of the total 1990 carbon dioxide emissions from the Annex I group.[27] The United States had the largest share of Annex I emissions in 1990, at 34.6 percent. Even without participation from the United States, however, the Protocol still could enter into force for the other signatories.

The *IEO2002* reference case projections indicate that energy-related carbon dioxide emissions from the entire Annex I group of countries will exceed the group's 1990 emissions level by 12 percent in 2010 (Figure 90). Taking the prescribed Kyoto emission reduction targets on the basis of energy-related carbon dioxide emissions alone, the industrialized Annex I countries would face an emission limit of 2,579 million metric tons of carbon equivalent in 2010, or 27 percent less than their projected baseline emissions.[28] On the other hand, energy-related carbon dioxide emissions from the group of transitional Annex I countries have been decreasing throughout the 1990s as a result of economic and political crises in the EE / FSU. Baseline emissions from the transitional Annex I countries are projected to be 38 percent below their combined Kyoto Protocol reduction target by 2010.

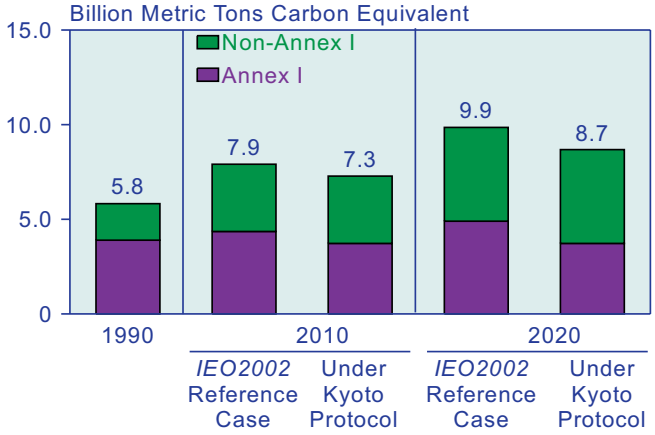
Greenhouse Gas Emissions Trading

At COP-7 in Marrakech, it was established that international emissions trading under the Kyoto Protocol could start as of 2008. In advance of any international emissions trading under the Protocol, however, some Annex I parties have established or are in the process of establishing their own internal greenhouse gas emissions trading programs. The economic rationale behind emissions trading is to reduce the costs associated with achieving a set reduction in greenhouse gases.

One framework for emissions trading is "cap and trade," whereby a regulatory authority establishes a permanent cap on aggregate emissions for a group of emitters. The cap may, for example, be set at a fraction of the historic emissions from the group of participants. The cap is divided into a set number of allowances, each of which gives the holder the right to emit a specified quantity of the regulated pollutant in a given compliance period. In the case of greenhouse gas emissions, each allowance could grant the holder the right to emit one metric ton of carbon dioxide equivalent. Once distributed among the participants, the allowances may be bought, sold, or (possibly) banked for future use. At the end of each compliance period, each participant must hold allowances equal to its actual emissions or else face a penalty. Although it has not been used to achieve a mandatory large-scale reduction of greenhouse gas emissions, the cap and trade system is not new, having been used in the United States during the 1990s to achieve reductions in stationary-source sulfur dioxide emissions.

Emissions trading can also be based on concepts other than cap and trade. An offsets or credit-based emissions trading system can incorporate capped and non-capped industries and entities that trade voluntarily created, permanent emissions reductions that are legally recognized by a regulator. This system essentially allows entities with emissions increases to obtain offsetting reductions from other entities. Other trading variants include baseline emissions trading systems, which allow entities to reduce emissions below a level that would otherwise occur under business as usual, and then trade the emissions reductions. Rate-based emissions trading focuses on the emission per unit of output rather than absolute emissions; entities that improve their efficiency beyond the target levels can trade the excess improvement with other companies.

Figure 90. Carbon Dioxide Emissions in Annex I and Non-Annex I Nations Under the Kyoto Protocol, 2010 and 2020



Sources: **1990:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, February 2001). **2010 and 2020:** World Energy Projection System (2002).

[27]The following 51 Parties to the Convention have ratified, accepted, acceded, or approved the Protocol as of March 28, 2002: Antigua and Barbuda, Argentina, Azerbaijan, Bahamas, Bangladesh, Barbados, Benin, Bolivia, Burundi, Colombia, Cook Islands, Cyprus, Czech Republic, Djibouti, Dominican Republic, Ecuador, El Salvador, Equatorial Guinea, Fiji, Gambia, Georgia, Guatemala, Guinea, Honduras, Jamaica, Kiribati, Lesotho, Malawi, Maldives, Malta, Mauritius, Mexico, Micronesia, Mongolia, Morocco, Nauru, Nicaragua, Niue, Palau, Panama, Paraguay, Romania, Samoa, Senegal, Trinidad and Tobago, Turkmenistan, Tuvalu, Uganda, Uruguay, Uzbekistan, and Vanuatu.

[28]The Kyoto Protocol emission targets are based on the average of emissions between 2008 and 2012—the first commitment period. Because 2010 is the midpoint of the first commitment period, it is commonly used as the reference year for calculating emissions reductions under the Kyoto agreement.

In October 2001, the EU released a final proposal for establishing its own internal greenhouse gas emissions trading system [***5***]. The first phase of the scheme would run from 2005 through 2007, regulating carbon dioxide emissions from all heat and electricity generators over 20 megawatts of rated thermal input capacity and from all refineries, coke ovens, iron and steel production processes, pulp and paper plants, and mineral industry installations. The proposal requires operators of such installations to hold permits as a condition for emitting greenhouse gases. The second phase of the scheme would be concurrent with the first compliance period under the Kyoto Protocol (2008-2012), should it come into force, and each subsequent phase would last for 5 years. The trading scheme may be extended to include all greenhouse gases after the first phase.

The EU member states would determine the quantity of allowances to be issued in each phase. During the first phase, with no legally binding limits on greenhouse gas emissions, allowances would be distributed free of charge. Noncompliance sanctions would be applied to any installation that did not have enough allowances to cover actual emissions each year. The allowances, which would be tradable across the entire EU could be banked from year to year within each phase but not across phases.

The EU proposal was designed to be compatible with the international emissions trading under the Kyoto framework and with some market-based instruments for emission reductions being developed in individual countries, such as tradable renewable energy certificates. Currently, Denmark is the only country that has instituted a mandatory cap and trade system to reduce carbon dioxide emissions from electricity producers. A cap of 22 million tons of carbon dioxide was set for 2001; the cap will decline by 1 million metric tons per year. The trading system became operational in April 2001 and will run through 2003. Free allowances were allocated to eight firms, based on their emissions during the 1994-1998 period. Should the program be extended, its allowances are likely to be compatible with the proposed EU trading scheme.

The compatibility of the EU proposal with the voluntary emissions trading program in the United Kingdom that is set to begin in April 2002 is more questionable. The programs differ in several aspects, including rules for participation, generation of allowances, and sectoral coverage. Under the British program, any company can opt to enter the trading scheme by negotiating energy efficiency targets or absolute emission reduction targets in return for incentive payments offered by the government, or by carrying out a project that results in a verified emissions reduction. Companies earn tradable allowances for carbon dioxide computed either from their targets or from the project-based reduction. At this point, it is unclear to what extent allowances earned under the UK scheme could be traded under the proposed EU scheme.

Abating Other Energy-Related Emissions

Many countries currently have policies or regulations in place that limit energy-related emissions other than carbon dioxide. Criteria pollutants such as sulfur oxides and nitrogen oxides are also emitted as a result of fossil fuel combustion, contributing to a variety of health and environmental problems that include acid rain, deterioration of soil and water quality, and human respiratory illnesses. Nitrogen oxide emissions additionally contribute to the formation of ground-level ozone (smog). Furthermore, criteria pollutants indirectly affect the global climate by reacting with other chemical compounds in the atmosphere to form greenhouse gases or, in the case of sulfur dioxide, by affecting the absorptive characteristics of the atmosphere.

To date, the measures taken to mitigate criteria pollutant emissions have been focused primarily on the main sources. Fossil fuel combustion for electricity generation, particularly coal-fired power, represents the largest source of sulfur dioxide emissions in many countries. Other significant energy-related sources include fuel combustion for manufacturing industries, vehicles, and petroleum refining. Nitrogen oxides are emitted as a result of fossil-fuel-based electricity generation, although oil use for road transportation is generally the single largest source.

With the tightening of emissions limitations on combustion plants, sulfur dioxide emissions fell in many industrialized countries during the 1990s. In Europe, the shift from coal to natural gas for electricity production (most notably in the United Kingdom and Germany) also contributed to the reduction in the region's sulfur dioxide emissions. Many industrialized countries have scheduled further restrictions on sulfur dioxide emissions from stationary sources to take effect over the next 10 years.

Despite the imposition of emissions regulations, nitrogen oxide emissions rose during the 1990s in most industrialized countries as a result of continued increases in consumption of transportation fuels. In Europe, however, the decrease in coal-fired electricity generation and the introduction of catalytic converters on vehicles actually led to a gradual drop in nitrogen oxide emissions [***6***]. To continue combating ground-level ozone formation, several countries plan to tighten their emissions standards for new vehicles over the

coming years (Table 26). Limits on the sulfur content of gasoline and diesel are also being required in order to ensure the effectiveness of the emissions control technologies used to meet the new vehicle standards (Table 27).

In the United States, the main initiatives to reduce emissions of criteria pollutants stem from the 1970 Clean Air Act—the comprehensive Federal law that regulates air emissions from stationary and mobile sources. Subsequent amendments to the Clean Air Act imposed emissions standards and requirements that the best available control technologies be used for new sources. Largely intended to address specific environmental problems, the Clean Air Act Amendments of 1990 (CAAA90) set emissions reduction goals for particular air pollutants and designated stricter emissions standards across a wider range of sources.

To control acid deposition, Title IV of CAAA90 sets a goal of reducing annual sulfur dioxide emissions by 10 million tons below 1980 levels and annual nitrogen oxide emissions by 2 million tons below 1980 levels. The sulfur dioxide program specifies a two-phase reduction in emissions from fossil-fired electric power plants greater than 25 megawatts in output capacity and from all new power plants. Phase II of the program, which began in January 2000, lowered the total allowable level of sulfur dioxide emissions from all electricity generators, capping annual emissions at 8.95 million metric tons by 2010.[29] Individual plant operators may reduce

Table 26. Current and Future Nitrogen Oxide Emission Standards for New Vehicles in Selected Countries

Vehicle Type	Vehicle Class	United States		European Union		Australia	
		Limit	Date	Limit	Date	Limit	Date
Gasoline . .	Light Duty	0.60-1.53 g/mile	Current standard	0.15-0.21 g/km	Current standard	0.63-1.40 g/km	Current standard
		0.07 g/mile	Phase-in 2004-2007	0.08 g/km[b]	Starting 2005	0.22 g/km	Starting 2003
				0.1-0.11 g/km[c]	Starting 2006	0.15-0.21 g/km	Starting 2005
	Heavy Duty	4.0 g/bhp-hr	Current standard				
		1.0 g/bhp-hr[a]	Starting 2004				
		0.2 g/bhp-hr	Phase-in 2008-2009				
Diesel	Light Duty	0.97-1.53 g/mile	Current standard	0.50-0.78 g/km	Current standard	0.78-1.20 g/km	Current standard
		0.07 g/mile	Starting 2004	0.25-0.39 g/km	Starting 2005	0.50-0.78 g/km	Starting 2003
	Heavy Duty	4.0 g/bhp-hr	Current standard	5.0 g/kWh	Current standard	8.0 g/kWh	Current standard
		1.0 g/bhp-hr[a]	Starting 2004	3.5 g/kWh	Starting 2005	5.0 g/kWh	Starting 2002
		0.2 g/bhp-hr	Phase-in 2007-2010	2.0 g/kWh	Starting 2008	3.5 g/kWh	Starting 2006

[a]Combined nitrogen oxide and hydrocarbon emissions limit.
[b]For passenger cars and class I light commercial vehicles.
[c]For other light commerical vehicles.
Note: The mix of vehicle types varies by region.
Sources: **United States:** U.S. Environmental Protection Agency, Office of Mobile Sources, *Emission Facts*, EPA-420-F-99-017 (Washington, DC, May 1999). **European Union:** European Parliament, Directive 98/69/EC, Official Journal L 350 (December 28, 1998), and Direcetive 99/96/EC, Official Journal L 44 (February 16, 2000). **Australia:** Department of Transpoprt and Regional Services, "Vehicle Emission Australian Design Rules (ADRs)" (August 7, 2001).

Table 27. Future Sulfur Content Limits on Motor Fuels in Select Countries

Fuel	United States		European Union		Australia	
	Limit	Date	Limit	Date	Limit	Date
Gasoline. .	30 ppm	Phase-in 2004-2006	50 ppm	As of 1/1/2005	500 ppm[a]	As of 1/1/2002
					150 ppm[b]	As of 1/1/2002
					150 ppm[c]	As of 1/1/2005
Diesel. . . .	15 ppm	As of 6/1/2006	50 ppm	As of 1/1/2005	500 ppm	As of 12/31/2002
					50 ppm	As of 1/1/2006

[a]For unleaded petrol and lead replacement petrol.
[b]For premium unleaded petrol.
[c]For all grades.
Sources: **United States:** U.S. Environmental Protection Agency, "Control of Air Pollution from New Motor Vehicles: Tier 2 Motor Vehicle Emission Standards and Gasoline Control Requirements," *Federal Register* (February 10, 2000). **European Union:** European Parliament, Directive 98/70/EC, Official Journal L 350 (December 28, 1998). **Australia:** Attorney General's Department, Office of Legislative Drafting, "Fuel Standards Quality Act of 2000: Fuel Standards (Diesel and Petrol)" (October 8, 2001).

[29]Because some power companies accumulated (banked) emissions allowances during Phase I of the program (1995 to 1999), the Phase II cap of 8.95 million tons per year will not be reached until the banked allowances have been exhausted.

their emissions through any combination of strategies, including installation of scrubbers, switching to low sulfur fuels, and emissions allowance trading and banking. Emissions reductions under the nitrogen oxide program, which targets certain coal-fired utility boilers, are also scheduled according to two phases. As with the sulfur dioxide program, the Phase II nitrogen oxide limits became effective in January 2000; however, the nitrogen oxide program neither sets an emissions cap nor incorporates emissions allowance trading as a compliance option. The program requires utility boilers to meet a specified nitrogen oxide emissions rate, depending on boiler capacity.

To reduce ozone formation, the U.S. Environmental Protection Agency has promulgated a multi-State summer season cap on power plant nitrogen oxide emissions that will take effect in 2004. The rules, commonly referred to as the "NO_x SIP Call," require abatement efforts greater than those required to comply with the nitrogen oxide limits under Title IV of CAAA90. Additional requirements for electric power plant operators to reduce sulfur dioxide and nitrogen oxide emissions beyond the levels called for in current regulations are being considered at both the Federal and State levels. Power plant operators may also face requirements to reduce mercury and carbon dioxide emissions. At present, neither the future reductions nor the timing for compliance is known for any of these airborne emissions (see box on page 171).

CAAA90 also designates more stringent emissions standards for motor vehicles. The "Tier 1" standards cover emissions of several pollutants from light-duty vehicles, beginning with model year 1994. Tighter "Tier 2" standards will be phased in starting in 2004, marking the first time that both cars and light-duty trucks will be subject to the same national pollution control system in the United States. The current emissions standards for heavy-duty vehicles, which have been in place since 1998, will be further tightened in two stages: a new combined nitrogen oxide and hydrocarbon emission standard will take effect in 2004, and further emission reductions will be phased in starting in 2007 [***7***, ***8***].

Concurrent with the introduction of Tier 2 emissions standards, the U.S. Government is requiring a reduction in the sulfur content of gasoline and diesel used for transportation [***9***, ***10***]. The new gasoline sulfur standard will be phased in between 2004 and 2007, in order to ease the transition for domestic refineries. By June 1, 2006, refiners and importers must produce highway diesel according to the new standard, although the law incorporates a phase-in period and hardship provisions for small refiners through May 2010.

In Canada, efforts to abate sulfur dioxide emissions have focused on the seven easternmost provinces, where acid rain has already begun to damage sensitive ecosystems.[30] The Eastern Canada Acid Rain Program placed a region-wide cap on sulfur dioxide emissions at 2.3 million metric tons per year for 1994, mostly restricting emissions from large industrial facilities. Some provinces extended the emissions cap through 2000 and beyond. Recently, further sulfur dioxide emission reduction targets were announced by Ontario, Quebec, New Brunswick, and Nova Scotia for the 2002-2015 time frame.

Addressing the problems of acid rain and ground-level ozone in Canada has required cooperation from the United States, given the transboundary flows of air pollutants between the two countries. Actions taken under the various sulfur dioxide and nitrogen oxide programs of the U.S. CAAA90 have supplemented Canada's domestic efforts. Recently, new measures at federal and provincial levels in Canada were enacted to reduce their nitrogen oxide emissions. Starting in 2007, fossil fuel power plants in central and southern Ontario will face an annual cap of 39,000 tons, and emissions from plants in southern Quebec will be capped at 5,000 tons.

Until recently, Canada's emission regulations for light-duty vehicles were aligned with those of the United States for the 1998 model year. The Canadian government has now reached an agreement with vehicle manufacturers to equip new light-duty vehicles and trucks sold with the same emissions control and monitoring equipment needed to meet the U.S. Federal emissions standards for the 2001-2003 model years. Canada will also require a diesel fuel sulfur cap of 15 parts per million by June 2006, mirroring the U.S. highway diesel regulation.

In Europe, efforts to limit aggregate emissions of sulfur dioxide and nitrogen oxides were first coordinated under the 1979 United Nations/European Economic Commission Convention on Long-Range Transboundary Air Pollution (CLRTAP), which was drafted after scientists demonstrated the link between sulfur dioxide emissions in continental Europe and the acidification of Scandinavian lakes. Since its entry into force, the Convention has been extended by eight protocols that set emissions limits for a variety of pollutants. The 1999 Gothenburg Protocol calls for national emissions ceilings for sulfur dioxide and nitrogen oxides. As with previous CLRTAP protocols, the Gothenburg Protocol specifies tight limit values for specific emissions sources based on the critical loads concept, and requires best available technologies to be used to achieve the

[30]The seven Canadian provinces covered under the Eastern Canada Acid Rain Program are Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Newfoundland, and Prince Edward Island.

Multiple Emissions Controls in U.S. Electricity Markets

Electric power plant operators in the United States may face new requirements to reduce emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) beyond the levels called for in current regulations. They could also face requirements to reduce carbon dioxide (CO_2) and mercury (Hg) emissions. At present neither the future reductions nor the timing for compliance is known for any of these airborne emissions. Given these uncertainties, compliance planning is difficult for plant owners.

Until recently, each of these environmental issues was addressed through separate regulatory programs, many of which are undergoing modification. To control acidification, the Clean Air Act Amendments of 1990 (CAAA90) required operators of electric power plants to reduce emissions of SO_2 and NO_x. Phase II of the SO_2 reduction program—lowering allowable SO_2 emissions to an annual national cap of 8.95 million tons—became effective on January 1, 2000.[a] More stringent NO_x emissions reductions are required under various Federal and State laws taking effect from 1997 through 2004. For example, in 1997 the U.S. Environmental Protection Agency (EPA) issued new standards for particulate matter and ozone. The ozone standard was tightened from 0.12 parts per million measured over 1 hour to 0.08 parts per million measured over 8 hours. States are also beginning efforts to address visibility problems (regional haze) in national parks and wilderness areas throughout the country. Because electric power plant emissions of SO_2 and NO_x contribute to the formation of regional haze, States could require that these emissions be reduced to improve visibility in some areas. In the near future, it is expected that new national ambient air quality standards for ground-level ozone and fine particulates may necessitate additional reductions in NO_x and SO_2 emissions.

To reduce ozone formation, the EPA has promulgated a multi-State summer season cap on power plant NO_x emissions that will take effect in 2004. Emissions that lead to fine particles (less than 2.5 microns in diameter), their impacts on health, and the level of reductions that might be required are currently being studied. Fine particles are associated with power plant emissions of NO_x and SO_2, and further reductions in NO_x and SO_2 emissions could be required by as early as 2007 in order to reduce emissions of fine particles. In addition, the EPA decided in December 2000 that Hg emissions must be reduced; proposed regulations will be developed over the next 3 years, possibly as part of a multi-emissions reduction strategy. Further, if the United States decided that emissions of greenhouse gases need to be mitigated, energy-related CO_2 emissions would also have to be reduced.[b]

Because the timing and levels of emission reduction requirements under the new standards are uncertain, compliance planning is complicated. It can take several years to design, license, and construct new electric power plants and emission control equipment, which may then be in operation for 30 years or more. As a result, power plant operators must look into the future to evaluate the economics of new investment decisions.

The potential for new emissions standards with different timetables adds considerable uncertainty to investment planning decisions. An option that looks attractive to meet one set of SO_2 and NO_x standards may not be attractive if further reductions are required in a few years. Similarly, economical options for reducing SO_2 and NO_x today may not be the optimal choice in the future if Hg and CO_2 emissions must also be reduced.

Further complicating planning, some investments capture multiple emissions simultaneously, such as advanced flue gas desulfurization equipment that reduces SO_2 and Hg, making such investments more attractive under some circumstances. As a result, power plant owners currently are wary of making investments that may prove unwise a few years hence. Aware of these difficulties, both the previous and current Congresses have proposed legislation that would require simultaneous reductions of multiple emissions.

There have been three Congressional requests to the Energy Information Administration (EIA) for analyses of proposed legislation for reductions of multiple emissions. The Subcommittee on National Economic Growth, Natural Resources, and Regulatory Affairs of

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[a]A description of the legislation is available at web site www.epa.gov/oar/caa/contents.html.

[b]On February 14, 2002, President Bush proposed that U.S. businesses voluntarily track and reduce their output of greenhouse gases. He proposed that goals for reductions be tied to the growth rate of the economy. It is believed that this approach will minimize the loss in economic efficiency. The President''s proposal for multiple emissions controls would cut annual sulfur dioxide emissions by 73 percent, from current emissions of 11 million tons to caps of 4.5 million tons in 2010 and 3 million tons in 2018. It would cut emissions of nitrogen oxides by 67 percent, from current emissions of 5 million tons to caps of 2.1 million tons in 2008 and 1.7 million tons in 2018. Mercury emissions would be reduced by 69 percent, from current emissions of 48 tons to caps of 26 tons in 2010 and 15 tons in 2018. The President's proposal for control of multiple emissions is available at web site www.whitehouse.gov/news/releases/2002/02/clearskies.html.

Multiple Emissions Controls in U.S. Electricity Markets (Continued)

the U.S. House of Representatives Committee on Government Reform[c] asked EIA to "analyze the potential costs of various multi-emissions strategies to reduce the air emissions from electric power plants."[d] The Subcommittee requested that EIA examine cases with alternative NO_x, SO_2, CO_2, and Hg emission reductions, with and without a renewable portfolio standard (RPS) requiring a specified portion of all electricity sales to come from generators that use nonhydroelectric renewable fuels.

In the cases specified by the Subcommittee, emissions of NO_x and SO_2 were to be reduced to 75 percent below 1997 levels beginning in 2002, and compliance was to be achieved by 2008. CO_2 emissions were required to be reduced to 1990 levels by 2008 and 7 percent below 1990 levels by 2012. Hg emissions were to be reduced by 90 percent from 1997 levels by 2008. The RPS was targeted to reach 20 percent by 2020. The analysis examined the impacts of these requirements both for individual emissions and for all emissions taken together.

In a second study, requested by Senators Smith, Voinovich, and Brownback, EIA was asked to examine the costs of different multi-emissions reduction strategies for NO_x, SO_2, and Hg. The Senators also requested an analysis of the potential costs of requiring power suppliers to acquire offsets for any increases in CO_2 emissions beyond the levels currently expected for 2008. The request called for 50- to 75-percent reductions in NO_x below 1997 levels, 50- to 75-percent reductions in SO_2 emissions below full implementation of CAAA90 Title IV, and 50- to 75-percent reductions in Hg emissions below 1999 levels, with half the reductions to be achieved by 2007 and the full reductions to occur by 2012. The emissions reduction programs, covering all electricity generators other than cogenerators producing both electricity and useful thermal output, were patterned after the SO_2 allowance program created in the CAAA90. One-half of the reductions in Hg emissions were to come from site-specific reductions.[e]

A third analysis, requested by Senators Jeffords and Lieberman, was to examine the potential impacts of limits on SO_2, NO_x, CO_2, and Hg emissions from electricity generators.[f] Using 2002 as a start date for emissions reductions, the request specified that, by 2007, NO_x emissions from electricity generators were to be reduced to 75 percent below 1997 levels, SO_2 emissions to 75 percent below the full implementation of the Phase II requirements under CAAA90 Title IV, Hg emissions to 90 percent below 1999 levels, and CO_2 emissions to 1990 levels. It was assumed that the emissions limits would be applied to all electricity generators, excluding cogenerators. This analysis examined the impacts of the specified limits or "caps" on electricity-sector emissions of SO_2, NO_x, Hg, and CO_2 under four scenarios with different assumptions about technology cost and performance, energy policies, and consumer behavior.

Emission caps imposed were assumed to be implemented under a "cap and trade" system patterned after the SO_2 CAAA90 allowance program.[g] All electricity generators, excluding cogenerators, were assumed to be covered by the emissions caps. Electricity generators were assumed to behave competitively, incorporating the costs of emissions allowances in their electricity bid prices. The cases included all energy laws and regulations in effect as of July 1, 2000, including the NO_x and SO_2 regulations established in the CAAA90, plus the new appliance efficiency standards announced in January 2001, as modified by the Bush Administration.

There are common findings across the three Congressional analyses of multiple emissions strategies. Generally, the costs of implementing multiple emissions strategies vary with the stringency of the reductions required and, to a lesser extent, the time frame for compliance. The costs of multiple emissions strategies also vary widely depending on whether CO_2 controls are included or excluded. The impacts of multiple emissions controls for SO_2, NO_x, and Hg that exclude CO_2

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[c]In the 107th Congress, this subcommittee was renamed the Subcommittee on Energy Policy, Natural Resources and Regulatory Affairs.

[d]Energy Information Administration, *Analysis of Strategies for Reducing Multiple Emissions from Electric Power Plants: Sulfur Dioxide, Nitrogen Oxides, Carbon Dioxide, and Mercury and a Renewable Portfolio Standard*, SR/OIAF/2001-03 (Washington, DC, July 2001), web site www.eia.doe.gov/oiaf/servicerpt/epp/index.html.

[e]Energy Information Administration, *Reducing Emissions of Sulfur Dioxide, Nitrogen Oxides, and Mercury from Electric Power Plants*, SR/OIAF/2001-04 (Washington, DC, September 2001), web site www.eia.doe.gov/oiaf/servicerpt/mepp/pdf/sroiaf(2001)04.pdf.

[f]Energy Information Administration, *Analysis of Strategies for Reducing Emissions from Electric Power Plants with Advanced Technology Scenarios*, SR/OIAF/2001-05 (Washington, DC, October 2001), web site www.eia.doe.gov/oiaf/servicerpt/eppats/pdf/sroiaf(2001)05.pdf.

[g]Numerous policy instruments are available, including taxes, maximum achievable control technology, no-cost allowance allocation with cap and trade, allowance auction with cap and trade, and generation performance standard allowance allocation with cap and trade. Each of these options would have different price and cost impacts.

emissions reductions. To date, Luxembourg is the only country that has ratified the Gothenburg Protocol. Parallel to CLRTAP developments, the EU has been considering other proposals for national emissions ceilings for sulfur dioxide, nitrogen oxides, volatile organic compounds, and ammonia at levels that are stricter than those set under the Gothenburg Protocol [***11***].

Specific measures for abating sulfur dioxide and nitrogen oxide emissions are already defined in a number of existing EU directives. The Large Combustion Plant Directive of 1988 and subsequent amendments impose emissions limits for sulfur dioxide and nitrogen oxides on existing and new plants with a rated thermal input capacity greater than 50 megawatts. For plants licensed before July 1, 1987, the Directive places a gradually declining ceiling (cap) on total annual emissions of each pollutant. The ceiling values are differentiated by country. The Directive does not stipulate how the emissions reductions are to be achieved, although the general approach used by several European countries has been to require the use of specific emissions control technologies and combustion fuels. All plants licensed after July 1, 1987, face uniform emissions limit values, which are set according to plant capacity size and fuel type. The EU is considering a proposal to tighten the air pollution limits from new combustion plants in line with the substantial technical progress that has been made in this sector. The proposed emission limits for new plants are twice as strict as the current limits [***12***].

Nitrogen oxide emissions from motor vehicles have been regulated in Europe since the 1970 Motor Vehicle Directive. The most stringent vehicle emission limits were passed in 1998 and 1999 by Directives 98/69/EC and 99/96/EC. As the law currently stands, all new vehicles must meet the so-called "Euro 3" emissions standards by 2000 and 2001, depending on weight class. Between 2005 and 2008, the tighter Euro 4 and Euro 5 standards for new vehicles will take effect. Directive 98/70/EC designates current and future sulfur content limits for motor fuels. Germany, the Netherlands, Belgium, and the United Kingdom have encouraged the switch to low-sulfur gasoline and diesel by offering tax incentives. Sweden already requires all of its "city diesel" to meet the same sulfur standard (50 parts per million) required by the EU in 2005. Currently, the EU is considering a proposal that includes the mandatory introduction of sulfur-free motor fuels[31] by January 1, 2005, and a complete ban on all non-sulfur-free fuels by January 1, 2009 [***13***, ***14***]. The implementation of the measure would coincide with the introduction of Euro 4 vehicles in the European market.

In Australia, measures to reduce sulfur dioxide and nitrogen oxide emissions have been focused primarily on the transportation sector. Although Australia relies heavily on domestic coal for electricity generation, it has a lower sulfur content than the coal produced in most other countries. The ambient air quality concentrations of sulfur dioxide in most Australian towns and cities usually have remained well within a level that the government deems to be safe. Because of the health risks associated with high concentrations of nitrogen dioxide, particular in urban centers, the Australian government has begun to implement measures to reduce current and

Multiple Emissions Controls in U.S. Electricity Markets (Continued)

are significantly less than the results discussed here where CO_2 controls are included.

The higher the requirement to reduce CO_2 emissions and the shorter the time frame for the reductions, the higher the costs are expected to be. For example, when the emission reduction requirements are increased from 75 percent in the analysis that excludes CO_2 limits to 90 percent in the Jeffords-Lieberman reference case, which includes CO_2 limits, the projected cumulative resource costs (including fuel, operations and maintenance, and investment costs) to achieve them increase from $89 billion to $177 billion.

Higher resource costs and higher electricity prices to consumers are projected in all the multiple emissions cases analyzed. Electricity prices increase as a result of investments in emission control technologies, purchases of allowances, construction of new generating equipment to replace existing equipment, and higher fuel costs.

In all the analyses, higher electricity prices result in part from increases in natural gas consumption and the attendant high prices for natural gas in the emissions limits cases over the prices that would be expected without emissions limits. Natural gas consumption increases because it has lower emissions than other fossil fuels, particularly coal. Nuclear power and renewable energy sources also have lower emissions than either coal or natural gas. When emissions limits are assumed, the use of coal as a fuel for electricity generation is less desirable, and as a result consumption declines. In most of the cases that include caps on CO_2 emissions, coal-fired generation in 2020 declines to about one-half the level expected without CO_2 emissions limits.

[31] Gasoline and diesel fuel with sulfur content below 10 parts per million.

future emissions. Approximately 80 percent of the nitrogen dioxide emissions in Australian cities come from motor vehicle exhaust [***15***].

Vehicle emissions in Australia are regulated under the Motor Vehicle Standards Act of 1989. The most stringent emissions standards for new vehicles were set in December 1999, based on the schedule of vehicle standards used in the EU. According to the new Australian Design Rule 79/00, Euro 2 standards for all new light-duty vehicles will be phased in according to weight class and fuel type, starting in 2002. Rule 79/01 applies the Euro 3 standard for all new light-duty gasoline-powered vehicles starting in 2005 and the Euro 4 standard for all new light-duty diesel-powered vehicles starting in 2006. Rules 80/00 and 80/01 similarly phase in Euro 3 and Euro 4 emissions standards for new medium- and heavy-duty vehicles.

The high sulfur content of gasoline and diesel in Australia was identified as a particular problem for the effective operation of engine catalysts needed to meet tighter emission standards. In May 2001, the Australian government announced the first fuel quality standards to be adopted under the Fuel Quality Standards Act of 2000. Standards for gasoline and diesel will apply starting in 2002, in order to ensure compatibility between the fuels and the vehicle emissions control technologies that will start to come into use at that time. The government plans to develop standards for other fuels over time.

In Japan, the regulation of sulfur oxides and other particulate emissions from fuel combustion began after the passage of the Air Pollution Control Law of 1968. Emissions standards were established by order of the Prime Minister's Office and were last amended in 1998. Limit values for sulfur oxide emissions from stationary sources vary according to the geographic location of the facility and height of the exhaust stack, and nitrogen oxide emission limit values vary according to boiler or furnace type. Sulfur content limits for fuels were included under the Air Pollution Control Law by amendments in 1995 and have been in force since 1996. Vehicle emissions standards were also established by the Air Pollution Control Law and by the Automobile NO_x Law of 1992.

Some developing countries have also enacted targeted air pollution abatement measures designed to limit energy-related emissions including sulfur dioxide and nitrogen oxide. Compliance with emissions regulations is often low in developing countries, however, particularly in the transportation sector, due to inadequate means for measuring emissions levels accurately and enforcing emissions standards [***16***]. Thus, in the face of strong population growth and economic development, emissions of criteria pollutants in urban centers of the developing world have increased steadily.

Urban air quality in India ranks among the world's poorest [***17***]. Efforts to improve urban air quality have focused significantly on vehicles, which account for the majority of the country's criteria pollutant emissions. Emissions limits for gasoline and diesel-powered vehicles came into force in 1991 and 1992, respectively. Emissions standards for passenger cars and commercial vehicles were tightened in 2000 at levels equivalent to the Euro 1 standards. For the metro areas of Delhi, Mumbai, Chennai, and Kolkata, tighter Euro 2 standards have been required since 2001, and the sulfur content of motor fuels sold in the four metro areas has also been restricted to 500 parts per million since 2001, in order to be compatible with the tighter vehicle emissions standards. Since January 2000, motor fuel sulfur content in all other regions of the country has been limited to 2,500 parts per million.

The measures taken to reduce vehicle emissions in New Delhi have been more controversial. In 1998, India's Supreme Court ordered all of the city's buses to be run on compressed natural gas by March 31, 2001. Compliance was to be achieved either by converting existing diesel engines or by replacing the buses themselves. Only 200 compressed natural gas buses were available by the initial deadline (out of a total fleet of 12,000), and protests ensued as all other buses were banned from use [***18***]. To ease the transition for both bus owners and commuters, the Delhi government is now allowing for a gradual phaseout of the existing diesel bus fleet [***19***].

Although India is a large coal consumer, the country's Central Pollution Control Board has not set any sulfur dioxide emissions limits for coal-fired power plants, because most of the coal mined in India is low in sulfur content. Coal-fired power plants do not face any nitrogen oxide emissions limits either, although natural gas and naphtha-based thermal plants face emissions standards between 50 parts per million and 100 parts per million, depending on their capacity. Enforcement of the standards has been recognized as a major problem in India [***20***].

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